SCIENCE FOR CERAMIC PRODUCTION

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SPECIFICS OF SEMI-STIFF MOLDING OF CERAMICS

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Variations in the technological parameters of plastic ceramic mixtures are considered for the case where the mixture moisture approaches the lower bound of plasticity. It is demonstrated that the use of vibration facilitates the healing of internal stresses and makes it possible to improve the physicomechanical properties of articles under lower molding pressures.

One of the directions for upgrading the technology of ceramic production is molding ceramics from plastic mixtures, whose moisture approaches the lower bound of plasticity, what is known as semi-stiff mixtures. These mixtures contain a minimum quantity of free moisture and have an increased plastic strength, which makes it possible to mechanize and automate the process of molding and loading molded products on furnace cars and to use more rigorous drying conditions.

In this case the variations of the main technological parameters of plastic ceramic mixtures, whose moisture approaches the lower plasticity limit, are of special significance. Figure 1 shows that a decrease in the mixture moisture leads to a decrease in the drying sensitivity coefficient, and as the molding pressure grows, the drying sensitivity increases.

Clay mixed with water forms a mixture, in which water is arbitrarily distinguished as adsorption, capillary, and free water. As the clay particles interact with water, their surface is destroyed and a structurized gel layer is formed around the clay particles. The cohesion between the mixture particles is mainly due to the physicochemical bonds between the shells of the bonded water and the structurized gel, i.e., due to adsorption forces [1].

The bonded water and the structurized gel represent a viscous material that is displaced when pressure is applied to the mixture. The strength of the structure is largely determined by moisture. As the moisture decreases, the strength increases. This is accounted for by the thinning of the hydrate shells between the aggregates and, consequently, an increase in the intermolecular attraction forces and plastic strength. The pressure of the displacement of the argillaceous ceramic mixture depends on the maximum molecular saturation of the clay particle surface with water.

One of the methods for decreasing the plastic strength and effective viscosity of thixotropic systems at the moment of molding articles from semi-stiff mixtures is a temporary destruction of the entire volume of their structure and its subsequent restoration after molding. The most effective way for a uniform transfer of energy to a system volume is vibration. Particles under vibration acquire high relative velocities, which can lead to partial or full destruction of the structure and, when the vibration stops, the structure is not only fully restored but also exceeds in strength the initial structure [2].

The clay used to study the variations of the rheological properties of ceramic mixtures and the physicochemical properties of samples had a plasticity number of 18, a mold-

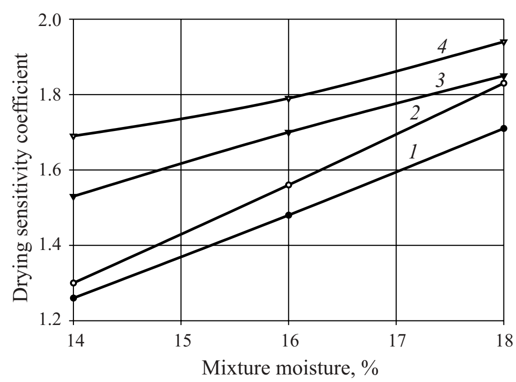

Fig. 1. Variation of the drying sensitivity coefficient depending on the moisture of the mixture under a molding pressure of 1.5 (*1*), 3.0 (*2*), 4.0 (*3*), and 6.0 MPa (*4*).

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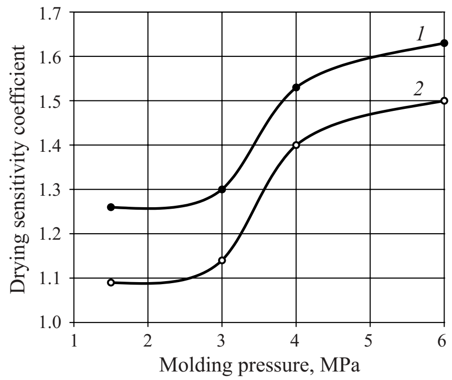

Fig. 2. Dependence of the drying sensitivity coefficient of a mixture of 14% moisture on molding pressure: *1*) without vibration; *2*) under vibration.

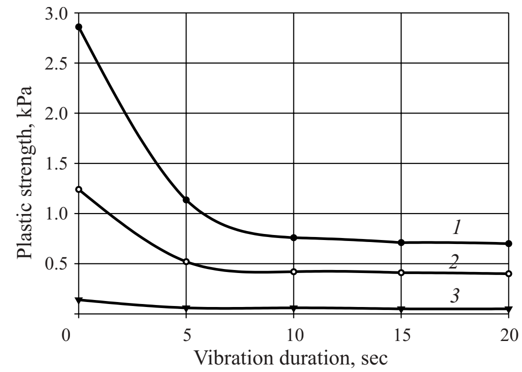

Fig. 3. Dependence of the plastic strength of a mixture on the vibration duration; mixture moisture equal to 14 (*1*), 16 (*2*), and 18% (*3*).

ing moisture of 18%, and a lower plasticity bound equal to 14%. The moisture of the mixture varied from 18 to 14% and the molding pressure varied from 1.5 to 6.0 MPa, without vibration or with vibration of 50 Hz frequency, amplitude of 0.8 mm, and lasting up to 20 sec.

A decrease in the mixture moisture from 18 to 14% produces an increase in the plastic strength of the mixture from 0.14 to 2.86 kPa, in the plastic viscosity from 2.95×10^5 to 11.05×10^5 Pa · sec, and an increase in the unit pressure at the beginning of the plastic fluidity of the mixture from 5.1 to 15.5 MPa.

As the moisture of the mixture decreases from 18 to 16% under the same molding pressure, the volume mass of the molded samples decreases by 5 – 9%, the air shrinkage becomes 1.5 – 1.6 times lower, and the drying sensitivity (determined by Nosova's method) is 1.3 times lower. With increase in the molding pressure to 6.0 MPa in mixtures with equal moisture, the drying sensitivity coefficient grows, especially within a pressure interval of 3.0 – 4.0 MPa (Fig. 2). This suggests that the determining factors in the modification of the mixture properties are the contact surfaces and the type of distribution of clay particles.

The study of the effect of the vibration duration on the considered properties of the mixtures indicated that as the vibration duration increases from 5 to 20 sec, the plastic strength of a mixture of constant moisture decreases. For instance the plastic strength of a mixture of 16% moisture under a 10-sec vibration decreases from 1.24 to 0.42 kPa, i.e., to one-third (Fig. 3). The plastic viscosity in this case decreases from 8.7×10^5 to 5.2×10^5 Pa · sec, i.e., 1.6 times, and the unit pressure at the beginning of plastic fluidity decreases from 9,62 to 6.41 MPa, i.e., 1.5 times. The effect of vibration increases as the moisture of the mixture decreases.

The decrease in the plastic strength and the plastic viscosity of ceramic mixtures under vibration can be accounted for by the fact that the force of collision of the microgranules grows when vibration is applied and, as a consequence, the structure of the microgranule shells is destroyed and the liquid phase spreads over the surface of the particles of the coarse-disperse solid phase. The spreading is implemented in waves. The vibration not only decreases the viscosity but also facilitates the healing of continuity disruptions and decreases internal stresses.

In studying the effect of vibration on the properties of samples, it was established that the volume mass of molded samples decreases as the moisture decreases, but to a lesser extent compared with the traditional molding. The shrinkage in this case decreases by 10% and the drying sensitivity coefficient decreases by 9.0%.

The superposition of a vibration field on a disperse system causes partial destruction of the structure, which makes it possible for the finely-disperse phase to become more homogeneously distributed on the particle surface, as a result of which the viscosity of the disperse system becomes significantly lower.

The use of vibration for ensuring a uniform structure in the mixture processed diminishes the probability of residual stresses arising in molding and the emergence of defects.

The drying sensitivity was determined according to the quick test proposed by A. F. Chizhskii on samples of 14% moisture under a molding pressure of 4.0 MPa. The first crack on the samples molded by the semi-stiff method without vibration was registered in 108 sec, whereas the first crack on the samples molded under vibration occurred in 132 sec, which is 1.21 times longer. This is another evidence of the formation of a more uniform structure, which facilitates a decrease in the internal stresses and a longer time until the emergence of the first crack.

The physicochemical testing of samples molded at 1.5 MPa and fired at 980°C indicates that a decrease in the molding moisture from 18 to 14% leads to a loss in the compressive strength from 31.15 to 21.46 MPa. However, when the molding pressure of samples of semi-stiff mixtures having 14.0% moisture grows from 1.5 to 6.0 MPa, the strength of the fired samples increases to 33.82 MPa, which is higher than the strength of samples made by plastic molding from a mixture of moisture 18%. The use of vibration in molding

samples from the same semi-stiff mixture makes it possible to reach a strength of 33.96 MPa under a lower unit pressure of molding (4.0 MPa).

Thus, in using the method of semi-stiff molding of ceramics, it is advisable to use vibration impact on ceramic mixtures in order to decrease the molding pressure and to achieve an increased strength in the products.

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